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[Title of the Invention] LIGHT EMITTING DEVICE

[What is claimed is]

[Claim 1] A light emitting device comprising a light  
5 emitting component whose light emitting layer is a nitride  
compound semiconductor and a phosphor which absorbs at least  
a part of light emitted by the light emitting component to emit  
light of a wavelength longer than that of the light emitted by  
the light emitting component, wherein

10 the phosphor is composed of two or more kinds of  
yttrium-aluminum oxide fluorescent materials activated with  
cerium having different compositions.

[Claim 2] The light emitting device according to claim 1,  
wherein the yttrium-aluminum oxide fluorescent material  
15 activated with cerium is  $(\text{Re}_x\text{Sm}_{1-x})_3(\text{Al}_y\text{Ga}_{1-y})_5\text{O}_{12}:\text{Ce}$  where  
 $0 < x \leq 1$  and  $0 \leq y \leq 1$  and Re is at least one selected from Y, Gd and  
La.

[Claim 3] The light emitting device according to claim 1,  
wherein the yttrium-aluminum oxide fluorescent material  
20 activated with cerium comprises an yttrium-aluminum oxide  
fluorescent material activated with cerium which has a main  
emission wavelength shorter than that of  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$  and an  
yttrium-aluminum oxide fluorescent material activated with  
cerium has a main emission wavelength longer than that of  
25  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$ .

[Claim 4] The light emitting device according to claim 1, wherein the yttrium-aluminum oxide fluorescent material activated with cerium comprises a first fluorescent material of  $Y_3(Al_{1-y}Ga_y)5O_{12}:Ce$  and a second fluorescent material of  $Re_3Al_5O_{12}:Ce$  having a main emission wavelength longer than that of the first fluorescent material, where  $0 \leq y \leq 1$  and Re is at least one selected from Y, Gd and La.

[Claim 5] The light emitting device according to claim 1, wherein the two or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium having different compositions comprise a third fluorescent material containing Gd and a fourth fluorescent material having a composition ratio of Gd higher than that of the third fluorescent material.

[Claim 6] The light emitting device according to claim 1, wherein a main emission peak of the light emitting component is within the range from 400 nm to 530 nm.

[Claim 7] The light emitting device according to claim 1, which is capable of planar light emission by means of optical coupling of a light emitting component and an optical guide plate via a color converting material having a phosphor arranged on the optical guide plate which is optically coupled with the light emitting component or a color converting material having the phosphor.

[Claim 8] A light emitting device which is a light emitting diode comprising a light emitting component placed in

a cup of a mount lead, an inner lead electrically connected with the light emitting component with a conductive wire, a coating material filling the cup and a molding material covering at least part of the coating material, the light emitting component, 5 the conductive wire, the mount lead and the inner lead, wherein a light emitting layer of the light emitting component is a nitride compound semiconductor and the coating material contains two or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium having different 10 compositions which absorb at least a part of the light emitted by the light emitting component to emit light of a wavelength longer than that of the light emitted by the light emitting component.

[Detailed Description of the Invention]

15 [0001]

[Industrial Utilization Field]

The present invention relates to a light emitting device used in back light source, illuminating switch, signal, display, LED display, indicator, etc. More particularly, it 20 relates to a light emitting device which emits lights of RGB (red, green, blue) colors with high luminance and high efficiency regardless of the operating environment.

[0002]

[Prior Art]

25 A light emitting device using a LED chip is compact

and emits light of clear color with high efficiency. It is also free from such a trouble as burn-out because it is a semiconductor element. It has an excellent initial drive characteristic and such an advantage as durability to endure vibration and repetitive ON/OFF operations. Thus it has been used in such applications as various indicators and various light sources. Recently light emitting diodes for RGB (red, green and blue) colors having ultra-high luminance and high efficiency have been developed. Accordingly, planar light sources for full color, which can be used in a liquid crystal back-light, using the three primary colors of RGB have been greatly advancing by making most of the advantages such as low power consumption, long life and light weight.

[0003]

15           The LED chip can emit light of various wavelengths ranging from ultra violet to infrared, depending on the semiconductor material and conditions to form a light emitting layer to be used. It also has favorable emission spectrum to generate monochromatic light.

20           [0004]

          Although because the light emitting diode has favorable emission spectrum to generate monochromatic light, making a light source for white light requires it to arrange the LED chips which are capable of emitting light of RGB colors closely to each other while diffusing and mixing the light

emitted by them. Although these light emitting diodes are effective as light emitting devices for emitting various colors freely, a set of red green and blue light emitting diodes or a set of blue-green and yellow light emitting diodes must be used even when generating white light only. A LED chip is a semiconductor and still includes considerable variations in the color tone and luminance. The LED chip which can emit lights of RGB colors with high luminance has not been yet made from the same semiconductor material. In case the LED chips which are semiconductor light emitting component are made from different materials, different LED chips require different drive voltages which must be supplied from different power sources provided separately. Therefore, white light must be generated by adjusting the current for each semiconductor.

Similarly, color tone is subject to variation due to the difference in temperature characteristics and chronological changes, because the LED chips are semiconductor light emitting components. Further, uneven color may result unless the light rays emitted by the LED chips are mixed evenly.

[0005]

Thus, the present applicant previously developed a light emitting diode which converts the color of light emitted by a LED chip by means of a fluorescent material and a planar light source disclosed in Japanese Patent Kokai Nos. 5-152609, 7-176794 and 8-8614. By using the light emitting diode and the



planar light source, light of other colors such as white color can be emitted by using a LED chip of one type.

[0006]

Specifically, a LED chip capable of emitting blue  
5 light is connected to one end of a transparent optical guide plate and light emitted by the LED chip is converted by a layer containing a fluorescent material provided on the optical guide plate into green and red light, thereby to produce light of white color. These devices can be used as light emitting devices  
10 which emit light for an extended period of time with a sufficient luminance, even when used as light emitting device capable of emitting light of white color having RGB light components.

[0007]

[Problems to be solved by the Invention]

15 There are various fluorescent materials such as fluorescent dye, fluorescent pigment and organic or inorganic compounds which are excited by light emitted by a LED chip. Excitation wavelengths and emission wavelengths of fluorescent materials also range widely. Also there are  
20 fluorescent materials which convert light of shorter wavelength emitted by a light emitting component into light of longer wavelength and those which convert light of longer wavelength emitted by a light emitting component into light of shorter wavelength.

25 [0008]

However, efficiency of conversion of long-wavelength light into short-wavelength light is extremely low and is not practical. When a light emitting device is used in outdoor environment such as under direct sunlight, or when a fluorescent material is located in the vicinity of the LED chip, the fluorescent material remains to be irradiated by high-energy radiations such as ultra violet ray of strong intensities for a long period of time. In particular, energy of light emitted by a semiconductor light emitting component having a high energy band gap enough to excite a fluorescent material and emit secondary radiation is inevitably high. Therefore, the fluorescent material itself is subject to deterioration due also to the synergistic effect with the extraneous light such as sun light.

15 [0009]

There are such cases as the color tone changes as the fluorescent material deteriorates or the fluorescent material is blackened resulting in lowered efficiency of extracting light. Similarly, the fluorescent material is exposed to a high temperature such as rising temperature of the LED chip and from the external environment. Further, although a light emitting device is usually sealed in a plastic casing, it is impossible to completely prevent the entry of moisture from the outside or to completely remove moisture which was contained during production. In the case of some fluorescent materials, such

moisture accelerates the deterioration of the fluorescent material due to the high-energy radiation or heat transmitted from the light emitting component. When it comes to an organic dye of ionic property, direct current electric field in the vicinity of the chip may cause electrophoresis, resulting in a change in the color tone. Therefore, an object of the present invention is to solve the problems described above and provide a light emitting device which is subject only to extremely low degrees of deterioration in light emission efficiency and color shift over a long period of time even when used outdoors, and is capable of emitting light of desired color with a high luminance.

[0010]

[Means for Solving the Problems]

The light emitting device of the present invention provides a light emitting device comprising a light emitting component whose light emitting layer is a nitride compound semiconductor and a phosphor which absorbs at least a part of light emitted by the light emitting component to emit light of a wavelength longer than that of the light emitted by the light emitting component, wherein

the phosphor is composed of two or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium having different compositions.

[0011]

With respect to the light emitting device of claim  
 2 of the present invention, the yttrium-aluminum oxide  
 fluorescent material activated with cerium is  $(\text{Re}_x\text{Sm}_{1-x})_3(\text{Al}_y\text{Ga}_{1-y})_5\text{O}_{12}:\text{Ce}$  (where  $0 < x \leq 1$  and  $0 \leq y \leq 1$  and Re is at least  
 5 one selected from Y, Gd and La).

With respect to the light emitting device of claim  
 3 of the present invention, the yttrium-aluminum oxide  
 fluorescent material activated with cerium comprises an  
 yttrium-aluminum oxide fluorescent material activated with  
 10 cerium which has a main emission wavelength shorter than that  
 of  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$  and an yttrium-aluminum oxide fluorescent  
 material activated with cerium has a main emission wavelength  
 longer than that of  $\text{Y}_3\text{Al}_5\text{O}_{12}:\text{Ce}$ .

[0012]

15 With respect to the light emitting device of claim  
 4 of the present invention, the yttrium-aluminum oxide  
 fluorescent material activated with cerium comprises a first  
 fluorescent material of  $\text{Y}_3(\text{Al}_y\text{Ga}_{1-y})_5\text{O}_{12}:\text{Ce}$  and a second  
 fluorescent material of  $\text{Re}_3\text{Al}_5\text{O}_{12}:\text{Ce}$  having a main emission  
 20 wavelength longer than that of the first fluorescent material  
 (where  $0 \leq y \leq 1$  and Re is at least one selected from Y, Gd and La).

With respect to the light emitting device of claim  
 5 of the present invention, the yttrium-aluminum oxide  
 fluorescent materials activated with cerium having different  
 25 compositions comprise a third fluorescent material containing

Gd and a fourth fluorescent material having a composition ratio of Gd higher than that of the third fluorescent material.

[0013]

With respect to the light emitting device of claim 5 6 of the present invention, a main emission peak of the light emitting component is within the range from 400 nm to 530 nm.

[0014]

The light emitting device of claim 7 of the present invention is a light emitting device capable of planar light 10 emission by means of optical coupling of a light emitting component and an optical guide plate via a color converting material having a phosphor arranged on the optical guide plate which is optically coupled with the light emitting component, or via a color converting material having the phosphor.

15 [0015]

A light emitting device of claim 8 of the present invention is a light emitting diode comprising a light emitting component placed in a cup of a mount lead, an inner lead electrically connected with the light emitting component by 20 means of a conductive wire, a coating material filling the cup and a molding material covering at least part of the coating material, the light emitting component, the conductive wire, the mount lead and the inner lead, wherein

a light emitting layer of the light emitting 25 component is a nitride compound semiconductor and the coating

material includes at least two kinds of yttrium-aluminum oxide fluorescent materials activated with cerium of different compositions which absorb at least a part of light emitted by the light emitting component and emit light of a wavelength  
5 longer than that of the light emitted by the light emitting component.

[0016]

[Action]

The light emitting device of the present invention  
10 has a light emitting component and fluorescent materials which are excited by light emitted by the light emitting component to emit light of a wavelength longer than that of the light emitted by the light emitting component. As the fluorescent materials, two or more kinds of yttrium-aluminum oxide  
15 fluorescent materials having different compositions are used.

This enables the light emitting device to emit light of a desired color with a high efficiency. That is, when the wavelength of the light emitted by the semiconductor light emitting component falls within the range from point A to point  
20 B in Fig. 8 depending on the semiconductor light emitting component, the device can emit light of any color within the shaded range enclosed by points C and D in Fig. 8 which are chromaticity points of at least two kinds of yttrium-aluminum oxide fluorescent materials of different compositions. The  
25 color can be controlled through the selection of composition

or quantities of the light emitting component and the fluorescent materials. The light emitting device can be caused to produce light of a desired wavelength by selecting various fluorescent materials and absorbing the variations in emission  
5 of the light emitting component. Also the light emitting device can be caused to generate light which includes RGB components with high luminance, by selecting the wavelengths of light emitted by the fluorescent materials.

[0017]

10 Moreover, the yttrium-aluminum oxide fluorescent material can be used to make a light emitting device capable of emitting light with a high luminance for a long period of time. Also by using a fluorescent material which emits light of a wavelength longer than that of the light emitted by the  
15 light emitting component, light can be emitted with a high efficiency. Because the converted light has a wavelength longer than that of the light emitted by the light emitting chip, it is less than the band gap of the light emitting chip and is less likely to be absorbed by the light emitting component.  
20 Therefore, even when light is emitted in isotropic way by the fluorescent material and is directed toward the light emitting component, it is not absorbed by the light emitting component, making it possible to emit light with a high efficiency.

[0018]

25 [Mode for carrying out the Invention]

The present inventors have found, as a result of various experiments, that it is made possible to prevent the decrease in emission efficiency and color shift through operation with a high luminance over a long period of time by selecting a particular semiconductor and a fluorescent material in a light emitting diode which uses a phosphor to convert the color of light emitted by a LED chip having a relatively high radiation energy in visible region, and have achieved the present invention.

10 [0019]

The phosphor used in the light emitting device of the present invention must satisfy the following requirements:

1. Excellent resistance against light, particularly durability to endure direct sun light in which lights with various high energy are radiated for a long period. And durability to endure light of a radiation illuminance as high as  $E_e=3\text{Wcm}^{-2}$  and more because the fluorescent material is exposed to intense radiation from a tiny region such as a semiconductor light emitting component when used as a light emitting diode.
2. Capability to emit light in blue region, not ultra violet, because mixing of colors with the light emitting elements is used.
3. Capability to emit light from green to red regions with high luminance in consideration of mixing with blue light.
4. Good temperature characteristic suitable for



location in the outdoor and in the vicinity of the light emitting component.

5. Capability to continuously change the color tone in terms of the proportion of composition or ratio of mixing a plurality of fluorescent materials.

6. Weatherability for the operating environment of the light emitting diode.

[0020]

As materials that satisfy the above requirements, the present invention uses a nitride compound semiconductor element having high-energy band gap in the light emitting layer as the light emitting component, and an yttrium-aluminum oxide fluorescent material activated with cerium where two or more kinds of phosphors of different compositions are activated with cerium as the phosphor. With this constitution, the light emitting device can emit light of a desired color tone by controlling two or more kinds of fluorescent materials, even when the wavelength of light emitted by the light emitting component deviates from the desired wavelength due to a problem in the production process of the light emitting component or other causes. More specifically,  $(\text{Re}x\text{Sm}1-x)_3(\text{Al}y\text{Ga}1-y)_5\text{O}12:\text{Ce}$  is used as the yttrium-aluminum oxide fluorescent material activated with cerium (where  $0 < x \leq 1$  and  $0 \leq y \leq 1$ , and Re is at least one selected from Y, Gd and La). This makes it possible to make a light emitting component which experiences

color shift of emitted light and a decrease in luminance of the emitted light, both of very low degrees, even when irradiated with high-energy radiation in the visible light region emitted by the light emitting component in the vicinity thereof over  
5 a long period of time or used outdoors, and emits light of desired component with high luminance.

[0021]

As one embodiment of the light emitting device, a chip type LED is shown in Fig. 1. A LED chip 102 employing gallium  
10 nitrate semiconductor is fixed in the casing of the chip type LED by means of epoxy resin or the like. The LED chip 102 employs a light emitting component having a  $\text{In}_{0.4}\text{Ga}_{0.6}\text{N}$  semiconductor light emitting layer with a thickness of 470 nm. The light emitting component has a contact layer which is a gallium  
15 nitride semiconductor having N type conductivity, a clad layer which is a gallium nitride semiconductor having P type conductivity and a contact layer which is a gallium nitride semiconductor having P type conductivity, formed on a sapphire  
20 substrate. Formed between the contact layer having N type conductivity and the clad layer having P type conductivity is a non-doped InGaN active layer of a single quantum well structure of thickness about 3 nm. (The sapphire substrate has a gallium nitride semiconductor formed thereon under a low temperature to make a buffer layer.) Electrodes of the light  
25 emitting component 102 and electrodes 105 provided on the casing

are electrically connected by means of gold wires 103 which are conductive wires. The LED chip which is a light emitting component, made by mixing and dispersing  $\text{Y3Al5O}_{12}:\text{Ce}$  as phosphor of green color and  $(\text{Y0.8Gd0.2})\text{3Al5O}_{12}:\text{Ce}$  as phosphor of red color in an acrylic resin, and the conductive wires are protected from extraneous stresses by a molding material 101 which is uniformly applied and cured. The LED chip is caused to emit light by supplying electric power to the light emitting device. By mixing blue light emitted by the LED chip and light emitted by two or more kinds of phosphor capable of emitting light of high luminance when excited by the light emitted by the LED chip, the light emitting diode can emit light of white color. The light emitting diode formed as described above does not have the light emitting pattern normally observed during emission of a conventional light emitting diode which does not include fluorescent material. The emission pattern generated by electrodes formed on the light emitting surface of the LED chip causing shadows are eliminated by diffusion caused by the fluorescent material. Thus the light emitting diode can emit light with uniform luminance. Constituents of the present invention will now be described below.

[0022]

(Phosphor)

The phosphor used in this invention refers to a phosphor which emits light when excited by visible light or

ultra violet light emitted by the semiconductor light emitting component. In the present invention, the phosphor uses two or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium of different compositions. Desired  
5 white color can be produced by mixing light of blue color emitted by a light emitting component employing nitride compound semiconductor in the light emitting layer, light of green color and light of red color emitted by the phosphor with yellow body color for absorbing blue light, or light of yellow color having  
10 greenish and reddish hue. In the light emitting device, in order to achieve this color mixture, it is preferable that the phosphor in the form of powder or bulk be contained in various resins such as epoxy resin, acrylic resin and silicon resin, or an inorganic substance such as silicon dioxide or aluminum  
15 oxide. Such a substance which includes phosphor can be used in various forms such as dot-shaped construction and a layer formed thin enough to transmit light from the LED chip. Various color colors containing white and incandescent lamp color can be produced by adjusting the mix proportion of phosphor and  
20 resin and the amount of coating or filling material and selecting the wavelength of light emitted by the light emitting device.

The light emitting device can be rendered weather-proof and other characteristics by changing the  
25 distribution of the phosphor. The distribution can be adjusted

by changing the material which includes the phosphor, forming temperature and viscosity and the shape and particle size distribution of the phosphor. Therefore, desired concentration of the fluorescent material can be selected  
5 depending on the operating conditions.

[0023]

Also the light emitting device can be made capable of emitting light with a high efficiency by arranging two or more fluorescent materials in an order with respect to the  
10 incident light coming from the respective light emitting components. That is, reflected light can be utilized effectively by laminating a color converting material which includes a fluorescent material having an absorbing wavelength on longer wavelength side and capable of emitting light of a  
15 long wavelength, and a color converting material which has an absorbing wavelength on further longer wavelength side and capable of emitting light of a long wavelength, on the light emitting component which has a reflecting material.

[0024]

20 By using the phosphor of the present invention, the light emitting device can be given enough light resistance for high-efficient operation even when arranged adjacent to or in the vicinity of a LED chip of radiation illuminance ( $E_e$ ) in a range from 3 Wcm<sup>-2</sup> up to 10 Wcm<sup>-2</sup>.

25 [0025]

YAG fluorescent material capable of emitting green light which is yttrium-aluminum oxide fluorescent material activated with cerium used in the present invention has garnet structure, and is therefore resistant to heat, light and moisture, thereby to be capable of absorbing excitation light having a peak at a wavelength near 450 nm as indicated by the solid line in Fig. 4(A). It emits light of broad spectrum having a peak near 510 nm tailing out to 750 nm as indicated by the solid line in Fig. 4(B). YAG fluorescent material capable of emitting red light which is yttrium-aluminum oxide fluorescent material activated with cerium used in the present invention, too, has garnet structure and is therefore resistant to heat, light and moisture, and is capable of absorbing excitation light having a peak near 450 nm as indicated by the wavy line in Fig. 4(A). It also emits light of broad spectrum having a peak near 600 nm tailing out to 750 nm as indicated by the wavy line in Fig. 4(B).

[0026]

Wavelength of the emitted light is shifted to a shorter wavelength by substituting part of Al, among the constituents of the YAG fluorescent material having garnet structure, with Ga, and the wavelength of the emitted light can be shifted to a longer wavelength by substituting part of Y with Gd and/or La. Proportion of substituting Al with Ga is preferably from Ga:Al=1:1 to 4:6 in consideration of the light

emitting efficiency and the wavelength of emission. Similarly, proportion of substituting Y with Gd and/or La is preferably from Y:Gd and/or La=9:1 to 1:9, or more preferably from Y:Gd and/or La=1:4 to 2:3. Substitution of less than 20% results  
5 in an increase of green component and a decrease of red component. Substitution of 80% or greater part, on the other hand, increases red component but decreases the luminance steeply.

[0027]

Material for making such a phosphor is made by using  
10 oxides of Y, Gd, Ce, La, Al, Sm and Ga or compounds which can be easily converted into these oxides at high temperatures, and sufficiently mixing these materials in stoichiometrical proportions. Otherwise, mixture material is obtained by dissolving rare earth elements Y, Gd, Ce, La and Sm in  
15 stoichiometrical proportions in an acid, coprecipitating the solution oxalic acid and sintering the coprecipitate to obtain an oxide of the coprecipitate, which is then mixed with aluminum oxide and gallium oxide. This mixture is mixed with an appropriate quantity of a fluoride such as ammonium fluoride  
20 used as a flux, and sintered in a crucible at a temperature from 1350 to 1450 °C in air for 2 to 5 hours. Then the sintered material is ground by ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0028]

25 The two or more kinds of yttrium-aluminum oxide

fluorescent materials activated with cerium of different compositions may be either used by mixing or arranged independently. When arranging the fluorescent materials independently, it is preferable to arrange in the order of a  
5 fluorescent material that absorbs light from the light emitting component of a shorter wavelength, then a fluorescent material that absorbs light of a longer wavelength. This arrangement enables efficient absorption and emission of light.

[0029]

10 (Light emitting components 102, 202, 302)

As the light emitting component used in the present invention, a nitride compound semiconductor capable of efficiently exciting the two or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium of different  
15 compositions may be used. The LED chip which is the light emitting component can be made by forming light emitting layer of semiconductor such as AlN, InN, GaN, InGaN or InGaAl on a substrate in the MOCVD process. The semiconductor structure may be homostructure, heterostructure or double-  
20 heterostructure which have MIS junction, PIN junction or PN junction. It may also be made in a single quantum well structure or multiple quantum well structure where a semiconductor active layer is formed in a thin film where quantum effect can occur.

While various wavelengths of emitted light can be selected  
25 depending on the property and structure of the semiconductor



layer material and the mixed crystal ratio thereof, it is preferable to emit light of a wavelength shorter than the wavelength of light emitted by the phosphor, in order to excite the phosphor more efficiently.

5 [0030]

When a nitride compound semiconductor is used, sapphire, spinel, SiC, Si, ZnO or the like is used as the semiconductor substrate. Use of sapphire substrate is preferable in order to form a nitride compound semiconductor of good crystallinity. A buffer layer of GaN, AlN, etc. is formed on the sapphire substrate, and a nitride semiconductor having PN junction is formed thereon. The gallium nitride semiconductor has N type conductivity under the condition of not doped with any impurity. In order to form an N type gallium nitride semiconductor having desired properties such as improved light emission efficiency, it is preferably doped with N type dopant such as Si, Ge, Se, Te, and C. In order to form a P type gallium nitride semiconductor, on the other hand, it is preferably doped with P type dopant such as Zn, Mg, Be, Ca, Sr and Ba. Because it is difficult to turn a gallium nitride compound semiconductor to P type simply by doping a P type dopant, it is preferable to anneal the gallium nitride compound semiconductor doped with P type dopant in such process as heating in a furnace, irradiation with low-speed electron beam, plasma irradiation, etc., thereby to turn it to P type. After exposing

10  
15  
20  
25

the surfaces of P type and N type semiconductor layers by etching or other process, electrodes of the desired shapes are formed on the semiconductor layers by sputtering or vapor deposition.

[0031]

5           Then the semiconductor wafer which has been formed is cut into pieces by means of a dicing saw which has a rotating blade having diamond cutting edge, or separated by an external force after cutting grooves (half-cut) which have width greater than the blade edge width. Or otherwise, the wafer is cut into  
10 chips by scribing grid pattern of extremely fine lines on the semiconductor wafer by means of a scriber having a diamond stylus which makes straight reciprocal movement. Thus the LED chips of gallium nitride compound semiconductor can be made.

[0032]

15           In order to emit white light with the light emitting device of the present invention, wavelength of main light emitted by the light emitting component is preferably from 400 nm to 530 nm inclusive in consideration of the mixing color with the phosphor, and more preferably from 420 nm to 490 nm inclusive.  
20   It is further more preferable that the wavelength be from 450 nm to 475 nm inclusive, so as to increase the emission efficiency of the LED chip and the phosphor, respectively.

[0033]

(Conductive wires 103, 303)

25           The conductive wires should have good electric

conductivity, good thermal conductivity and good mechanical connection with the electrodes of the light emitting components 102, 302. Thermal conductivity is preferably  $0.01 \text{ cal/cm}^2/\text{cm}/^\circ\text{C}$  or higher, and more preferably  $0.5 \text{ cal/cm}^2/\text{cm}/^\circ\text{C}$  or higher. For workability and other reasons, the diameter of the conductive wire is preferably from  $\phi 10 \text{ } \mu\text{m}$  to  $\phi 45 \text{ } \mu\text{m}$  inclusive. The conductive wire may specifically be a metal such as gold, silver, platinum and aluminum or an alloy thereof. Such a conductive wire can be easily connected to the electrodes of the LED chips, the inner lead 306 and the mount lead 305 by means of a wire bonding device.

[0034]

(Mount lead 305)

The mount lead 305 is used for mounting of the light emitting component 302, and suffices to have a size enough to load the LED chip 302 with a die bonding equipment or the like.

In case a plurality of LED chips are installed and the mount lead is used as common electrode of the LED chips, sufficient electric conductivity and good connecting characteristic with the bonding wires and the like are required. When the LED chip is installed in the cup of the mount lead and the cup is filled with the fluorescent material, erroneous illumination due to light from other light emitting diode mounted nearby can be prevented.

25 [0035]

Bonding of the LED chip 302 and the mount lead 305 with the cup can be achieved by means of a thermoplastic resin. Specifically, epoxy resin, acrylic resin and imide resin can be used. When bonding a face-down LED chip and the mount lead and, at the same time, electrically connecting them, Ag paste, carbon paste, metallic bump or the like can be used.

[0036]

Further, in order to improve the efficiency of light utilization of the light emitting diode, surface of the mount lead whereon the LED chip 302 is mounted may be mirror-polished to give reflecting function to the surface. In this case, the surface roughness is preferably from 0.1S to 0.8S inclusive. Electric resistance of the mount lead is preferably within 300  $\mu\Omega$ -cm and more preferably within 3  $\mu\Omega$ -cm.

15 [0037]

When mounting a plurality of LED chips on the mount lead, the LED chips generate significant amount of heat and therefore high thermal conductivity is required. Specifically, the thermal conductivity is preferably 0.01 cal/cm<sup>2</sup>/cm/°C or higher, and more preferably 0.5 cal/cm<sup>2</sup>/cm/°C or higher. Materials which satisfy these requirements include steel, copper, copper-clad steel, copper-clad tin and metallized ceramics.

[0038]

(Inner lead 306)

25 The inner lead 306 provides connection between the LED

chip mounted on the mount lead 305 and the conductive wire. When mounting a plurality of LED chips 302 on the mount lead, it is necessary to employ such a construction that the conductive wires can be arranged so as not to touch each other.

5 [0039]

Specifically, contact of the conductive wires with each other which connect the inner leads that are more distant from the mount lead can be prevented by increasing the area of the end face where the inner lead 306 is wire-bonded as the  
10 distance from the mount lead increases.

[0040]

Surface roughness of the end face connecting with the conductive wire is preferably from 1.6S to 10S inclusive in consideration of close contact. In order to form the tip of the  
15 inner lead in a desired shape, the shape may be formed by punching the lead frame with a die in advance, or by grinding off a part of inner leads at the top after forming all inner leads. Further, after forming by punching the inner leads, desired end face area and height can be formed simultaneously by applying pressure in  
20 the direction of end face.

[0041]

The inner lead is required to have good connectivity with the bonding wires which are conductive wires and good electrical conductivity. Specifically, the electric resistance  
25 is preferably within 300  $\mu\Omega$ -cm and more preferably within 3

$\mu\Omega$ -cm. Materials which satisfy these requirements include iron, copper, copper containing iron, copper containing tin, copper-, gold- or silver-plated aluminum, iron or copper.

[0042]

5 (Coating material 301)

The coating material 301 used in the present invention is provided in the cup of the mount lead 305 in addition to the molding material 304, and includes the phosphor which converts the light emitted by the LED chip 302. As the coating material,  
10 transparent materials of excellent weatherability such as epoxy resin, urea resin and silicon and glass are preferably employed.

A dispersant may be used together with the phosphor. As the dispersant, barium titanate, titanium oxide, aluminum oxide, silicon dioxide and the like are preferably used.

15 [0043]

(Molding material 101, 210, 304)

The molding may be provided in order to protect the LED, the conductive wire and the coating material which includes phosphor from external disturbance, depending on the application  
20 of the light emitting device. The molding material can be generally made of a resin or glass. The angle of view can be increased by containing the phosphor. And also, the angle of view can be further increased by adding a dispersant, thereby making the directivity of the emission from the LED chip dull.

25 [0044]

Further, the molding material may be formed in a desired shape having the function of lens to focus or diffuse the light emitted by the LED chip. Therefore, the molding material may be made in a structure of multiple layers laminated.

5 Specifically, it may be a convex lens or a concave lens, and may have an elliptic shape when viewed in the direction of optical axis, or a combination of these.

[0045]

As the molding material, transparent materials of  
10 excellent weatherability such as epoxy resin, urea resin and silicon resin, and glass having a low melting point are preferably employed. As the dispersant, barium titanate, titanium oxide, aluminum oxide, silicon dioxide and the like are preferably used.

The phosphor may be contained either in the molding material  
15 or in the coating material and other part. Or otherwise, the coating may be of other materials such as a resin containing phosphor and the molding material may be glass. In this case, such a light emitting diode can be made that is suited to mass production and is less affected by moisture. The molding and  
20 the coating may also be made of the same material in consideration of the refractive index.

[0046]

(Planar light source)

A planar light source which is one of light emitting  
25 devices of the present invention can be made either by turning

white light into planar light by means of an optical guide plate when emitting white light as shown in Fig. 2 (A), or by converting blue light emitted by the LED chip which emits planar light into white light as shown in Fig. 2 (B).

5 [0047]

When turning white light into planar light by means of an optical guide plate, it can be achieved either by such a construction that a light emitting diode 202 capable of emitting blue light and an optical guide plate 204 are arranged  
10 interposing a color conversion material 201 which includes phosphor, or by such a construction that the light emitting diode 202 having nitride semiconductor light emitting component which includes phosphor to be capable of emitting blue light and the optical guide plate 204 are optically coupled in a  
15 molding material 210 or the like.

[0048]

When converting blue light emitted by the LED chip 202 which emits planar light into white light, the light emitting diode 202, which includes a nitride semiconductor in  
20 the light emitting layer and is capable of emitting blue light, and the optical guide plate 204 are optically coupled and then contained in a diffusion sheet 206 on the optical guide plate 204, or otherwise applied on the diffusion sheet together with a binder resin to form a sheet. Further, such a construction  
25 may also be employed as a binder containing phosphor is formed



into dot-shape on the optical guide plate.

[0049]

Specifically, the LED chip which is the light emitting component is fixed in a metal substrate 203 or the like  
5 having inverted C shape whereon an insulation layer and a conductive pattern are formed. After electrically connecting the LED chip and the conductive pattern, epoxy resin is applied onto the substrate whereon the LED chip 202 is mounted, thereby to optically couple with an end face of the acrylic optical guide  
10 plate 204. Placed on the principal light emitting plane of the optical guide plate 204 is a sheet 201 made by applying a mixture of phosphor and epoxy resin uniformly on a diffusion sheet. The diffusion sheet 206 comprises a layer made by applying epoxy resin containing particles of aluminum oxide, silicon dioxide,  
15 titanium oxide or barium titanate as diffusion agent in a base of acrylic resin and a layer containing phosphor.

[0050]

It is preferable that a reflector film 207 containing a white diffusion agent be arranged on one principal plane of  
20 the optical guide plate for the purpose of preventing fluorescence wherein intense light is emitted from near the light emitting diode. Similarly, a reflector 205 is provided on the entire surface on the back of the optical guide plate 204 and on one end face where the light emitting diode is not  
25 provided, in order to improve the light emission efficiency.

With this construction, a planar light source can be obtained which generates enough luminance even when used as the back light of liquid crystal. Application to a liquid crystal display can be achieved by arranging a polarizer plate on the principal plane of the optical guide plate via liquid crystal injected between glass substrates whereon a translucent conductive pattern not shown in the drawing is formed. Examples of the present invention will be described below. It goes without saying that the present invention is not limited to the

10 Examples.

[0051]

[Examples]

(Example 1)

In<sub>0.05</sub>Ga<sub>0.95</sub>N semiconductor having emission peak at 15 450 nm is used as a light emitting component. A LED chip is made by flowing TMG (trimethyl gallium) gas, TMI (trimethyl indium) gas, nitrogen gas and dopant gas together with a carrier gas on a cleaned sapphire substrate and forming a gallium nitride compound semiconductor layer in MOCVD process. A 20 gallium nitride semiconductor layer having N type conductivity and a gallium nitride semiconductor layer having P type conductivity are formed by switching SiH<sub>4</sub> and Cp<sub>2</sub>Mg as dopant gas, thereby forming a PN junction. For the semiconductor light emitting component, a contact layer which is gallium nitride 25 semiconductor having N type conductivity, a clad layer which

is gallium nitride aluminum semiconductor having N type conductivity, a clad layer which is gallium nitride aluminum semiconductor having P type conductivity and a contact layer which is gallium nitride semiconductor having P type conductivity are formed. An active layer of Zn-doped InGaN which makes a double-hetero junction is formed between the clad layer having N type conductivity and the clad layer having P type conductivity. (A buffer layer is provided on the sapphire substrate by forming gallium nitride semiconductor layer at a low temperature. The P type semiconductor is annealed at a temperature of 400 °C or above after forming the film.)

After exposing the surfaces of P type and N type semiconductor layers by etching, electrodes are formed by sputtering. After scribing the semiconductor wafer which has been made as described above, LED chips are made as light emitting components by dividing the wafer with external force.

[0052]

The LED chip is mounted on a mount lead which has a cup at the tip of a silver-plated copper lead frame, by die bonding with epoxy resin. Electrodes of the LED chip, the mount lead and inner lead are electrically connected by wire bonding with gold wires.

[0053]

The lead frame with the LED chip attached thereon is placed in a bullet-shaped die and sealed with translucent epoxy

resin for molding, which is then cured at 150 °C for 5 hours, thereby to form a blue light emitting diode. The blue light emitting diode is connected to one end face of an acrylic optical guide plate which is polished on all end faces. On one surface and side face of the acrylic plate, screen printing is applied by using barium titanate dispersed in an acrylic binder as white color reflector, which is then cured.

[0054]

On the other hand, phosphors of green and red colors are made by dissolving rare earth elements of Y, Gd, Ce and La in an acid in stoichiometrical proportions, and coprecipitating the solution with oxalic acid. Oxide of the coprecipitate obtained by sintering this material is mixed with aluminum oxide and gallium oxide, thereby to obtain respective mixture materials. The mixture is then mixed with ammonium fluoride used as a flux, and sintered in a crucible at a temperature of 1400 °C in air for 3 hours. Then the sintered material is ground by ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0055]

120 Parts by weight of the first fluorescent material having a composition of  $Y_3(Al_{0.6}Ga_{0.4})_5O_{12}:Ce$  and capable of emitting green light, 100 parts by weight of the second fluorescent material having a composition of  $(Y_{0.4}Gd_{0.6})_3Al_5O_{12}:Ce$  and capable of emitting red light,

prepared in a process similar to that for the first fluorescent material, are sufficiently mixed with 100 parts by weight of an epoxy resin, to form a slurry. The slurry is applied uniformly onto an acrylic layer of thickness of 0.5 mm by means of a multi-coater and then dried to form a fluorescent material layer used as a color converting material having a thickness of about 30  $\mu\text{m}$ . The fluorescent material layer is cut into the same size as that of the principal light emitting plane of the optical guide plate, and arranged on the optical guide plate thereby to form the light emitting device. Measurements of chromaticity point and color rendering index of the light emitting device gave values of (0.29, 0.34) for chromaticity point (x, y) and 92.0 for Ra (color rendering index) which are approximate to 3-waveform fluorescent lamp. Light emitting efficiency of 121 m/W comparable to that of an incandescent lamp was obtained. Further in weatherability tests under conditions of energization with a current of 60 mA at room temperature, 20 mA at room temperature and 20 mA at 60 °C with 90% RH, no change due to the fluorescent material was observed.

[0056]

(Comparative Example 1)

According to the same manner as that described in Example 1 except for mixing the same quantities of a green organic fluorescent pigment (FA-001, manufactured by Synleuch Chemical Co.) and a red organic fluorescent pigment (FA-005,

manufactured by Synleuch Chemical Co.) which are perylene-derivatives for the first and the second phosphor, the formation of a light emitting diode and weatherability test were conducted. Chromaticity coordinates of the light emitting diode thus  
5 formed were  $(x, y) = (0.34, 0.35)$ . The weatherability test was conducted by irradiating with ultraviolet ray generated by carbon arc for 200 hours, representing equivalent irradiation of sun light over a period of one year, while measuring the luminance retaining ratio and color tone at various times during  
10 the test period. In a reliability test, the LED chip was energized to emit light at a constant temperature of 70 °C while measuring the luminance and color tone at different times. The results are shown in Fig. 6 and Fig. 7, together with Example 1.

15 [0057]

(Example 2)

A LED chip having  $\text{In}_{0.05}\text{Ga}_{0.95}\text{N}$  with emission peak at 450 nm was formed as a light emitting component according to the same manner as that described in Example 1. The LED chip  
20 was mounted on a mount lead which had a cup at the tip of a silver-plated copper lead frame, by die bonding with epoxy resin. Electrodes of the LED chip, the mount lead and inner lead were electrically connected by wire bonding with gold wires.

[0058]

25 On the other hand, phosphors of green and red colors

were made by dissolving rare earth elements of Y, Gd and Ce in an acid in stoichiometrical proportions, and coprecipitating the solution with oxalic acid. Oxide of the coprecipitation obtained by sintering it was mixed with aluminum oxide and gallium oxide, thereby to obtain respective mixture materials.

The mixture was mixed with ammonium fluoride used as a flux, and sintered in a crucible at a temperature of 1400 °C in air for 3 hours. Then the sintered material was ground by ball mill in water, washed, separated, dried and sieved thereby to obtain the desired material.

[0059]

40 Parts by weight of the first fluorescent material having a composition of  $Y_3(Al_{0.5}Ga_{0.5})_5O_{12}:Ce$  and capable of emitting green light, 40 parts by weight of the second fluorescent material having a composition of  $(Y_{0.2}Gd_{0.8})_3Al_5O_{12}:Ce$  and capable of emitting red light and 100 parts by weight of an epoxy resin were sufficiently mixed to form a slurry. The slurry was poured into the cup which is provided on the mount lead wherein the LED chip was placed. Then the resin containing the fluorescent material was cured at 130 °C for 1 hour. Thus a coating layer containing the fluorescent material in thickness of 120  $\mu m$  was formed on the LED chip. Concentration of the fluorescent material in the coating layer was increased gradually toward the LED chip. Further, the LED chip and the fluorescent material were molded with translucent

epoxy resin for the purpose of protection against extraneous stress, moisture and dust. A lead frame with the coating layer of phosphor formed thereon was placed in a bullet-shaped die and mixed with translucent epoxy resin and then cured at 150  
5 °C for 5 hours. Under visual observation of the light emitting diode formed as described above in the direction normal to the light emitting plane, it was found that the central portion was rendered yellowish color due to the body color of the phosphor.

[0060]

10           Measurements of chromaticity point, color temperature and color rendering index of the light emitting diode which was obtained as described above and capable of emitting white light gave values of (0.32, 0.34) for chromaticity point (x, y), 89.0 for Ra (color rendering index)  
15 and light emitting efficiency of 101 m/W. Further in weatherability tests under conditions of energization with a current of 60 mA at room temperature, 20 mA at room temperature and 20 mA at 60 °C with 90% RH, no change due to the phosphor was observed, showing no difference from an ordinary blue light  
20 emitting diode in the service life characteristic.

[0061]

(Example 3)

In<sub>0.4</sub>Ga<sub>0.6</sub>N semiconductor having an emission peak at 470 nm was used as a light emitting component. A LED chip was  
25 made by flowing TMG (trimethyl gallium) gas, TMI (trimethyl



indium) gas, nitrogen gas and dopant gas together with a carrier gas on a cleaned sapphire substrate and forming a gallium nitride compound semiconductor layer in MOCVD process. A gallium nitride semiconductor layer having N type conductivity  
5 and a gallium nitride semiconductor layer having P type conductivity were formed by switching SiH<sub>4</sub> and Cp<sub>2</sub>Mg used as the dopant gas, thereby forming a PN junction. For the semiconductor light emitting component, a contact layer which was gallium nitride semiconductor having P type conductivity,  
10 a clad layer which was gallium nitride aluminum semiconductor having P type conductivity and a contact layer which was gallium nitride semiconductor having P type conductivity were formed.

An active layer of non-doped InGaN which had single quantum well structure with thickness of about 3 nm was formed between  
15 the contact layer having N type conductivity and the clad layer having P type conductivity. (A buffer layer was provided on the sapphire substrate by forming a gallium nitride semiconductor layer at a low temperature.)

After exposing the surfaces of P type and N type  
20 semiconductor layers by etching, electrodes were formed by sputtering. After scribing the semiconductor wafer which was made as described above, LED chips were made as light emitting components by dividing the wafer with an external force.

[0062]

25 The LED chip was mounted on a mount lead provided with

a cup at the tip of a silver-plated copper lead frame, by die bonding with an epoxy resin. Electrodes of the LED chip, the mount lead and inner lead were electrically connected by wire bonding with gold wires.

5 [0063]

The lead frame with the LED chip attached thereon was placed in a bullet-shaped die and sealed with translucent epoxy resin for molding, which was then cured at 150 °C for 5 hours, thereby to form a blue light emitting diode. The blue light  
10 emitting diode was connected to one end face of an acrylic optical guide plate which was polished on all end faces thereof.

On one surface and side face of the acrylic plate, screen printing was applied by using barium titanate dispersed in acrylic binder as white color reflector, which was then cured.

15 [0064]

For the phosphor, a fluorescent material capable of emitting yellow light of a relatively short wavelength and a fluorescent material capable of emitting yellow light of a relatively long wavelength were used as two or more kinds of  
20 yttrium-aluminum oxide fluorescent material activated with cerium of different compositions. Rare earth elements of Y, Gd and Ce were dissolved in an acid in stoichiometrical proportions, and the solution was coprecipitated with oxalic acid. Oxide of the coprecipitate obtained by sintering the  
25 precipitate was mixed with aluminum oxide. The mixture was

mixed with ammonium fluoride used as a flux, and sintered in a crucible at a temperature of 1400 °C in air for 3 hours. Then the sintered material was ground by ball mill in water, washed, separated, dried and sieved thereby to obtain the desired  
5 material.

[0065]

100 Parts by weight of the fluorescent material having a composition of  $(Y_{0.8}Gd_{0.2})_3Al_5O_{12}:Ce$  and capable of emitting yellow light of a relatively short wavelength and 100  
10 parts by weight of the fluorescent material having a composition of  $(Y_{0.4}Gd_{0.6})_3Al_5O_{12}:Ce$  and capable of emitting yellow light of a relatively long wavelength, prepared in a process similar to that of the former, and 1000 parts by weight of an acrylic resin were well mixed and formed, by extrusion molding, into  
15 a fluorescent material layer as color conversion material in thickness of about 180  $\mu m$ . The fluorescent material layer was cut into the same size as the principal light emitting plane of the optical guide plate, and arranged on the optical guide plate thereby to form the light emitting device. Measurements  
20 of chromaticity point and color rendering index of the light emitting device gave values of (0.33, 0.34) for chromaticity point (x, y) and 88.0 for Ra (color rendering index). Light emitting efficiency of 101 m/W was obtained. Further in weatherability tests under conditions of energization with a  
25 current of 60 mA at room temperature, 20 mA at room temperature

and 20 mA at 60 °C with 90% RH, no change due to the fluorescent material was observed. Similarly, desired chromaticity point can be maintained even when the wavelength of light emitted by the light emitting component is changed by changing the  
5 concentration of the fluorescent material.

[0066]

[Effect of the Invention]

According to the present invention, by using a high-output light emitting component of nitride compound semiconductor and two or more kinds of phosphors of different  
10 compositions which emit light upon excitation by the light from the light emitting component, a light emitting device which maintains a high light emitting efficiency over a long period of operation with a high luminance and is capable of emitting  
15 light of desired color can be made. The light emitting component which excites the fluorescent material emits light of a short wavelength and is capable of exciting the fluorescent material efficiently, and the light radiated isotropically by the fluorescent material is not absorbed by the light emitting  
20 layer of the light emitting component. Therefore, even higher efficiency of emitting light is made possible when the light emitting component is arranged on a reflective material. With high reliability, energy saving performance, compact construction and capability to change color temperature, the  
25 present invention can open up new applications containing

display and illumination in automobile, aircraft and electric appliances in general, as well as outdoor use such as buoys for harbors and ports and sign and illumination for expressways.

Also the light emitting diode of the present invention is better  
5 for the human eyes because white light imposes less stimulation to the eye when watched for a long period of time.

[0067]

The construction described in claim 1 of the present invention, in particular, makes it possible to obtain a light  
10 emitting device capable of emitting white light having desired components with high luminance, with minimum color shift and deterioration in light emission efficiency, even when used over an extended period of time. Also a light emitting device of high color rendering index can be made by using two or more kinds  
15 of fluorescent materials of different compositions. Moreover, a light emitting device which has favorable characteristics for mass production and is capable of emitting light of constant color can be made by adjusting the compositions and concentrations of the fluorescent materials, even when the  
20 wavelength of light emitted by the light emitting component deviates.

[0068]

By making the light emitting device in the specific construction as described in claim 2 of the present invention,  
25 it is made possible to emit desired light with minimum color

shift and minimum deterioration in light emission efficiency,  
even when used over an extended period of time.

[0069]

By making the light emitting device in the  
5 construction as described in claim 3 of the present invention,  
it is made possible to emit white light with minimum color shift  
and minimum deterioration in light emission efficiency, even  
when used over an extended period of time.

[0070]

10 By making the light emitting device in the  
construction as described in claim 4 of the present invention,  
it is made possible to emit white light with minimum color shift  
and minimum deterioration in light emission efficiency, even  
when used over an extended period of time.

15 [0071]

By making the light emitting device in the  
construction as described in claim 5 of the present invention,  
it is made possible to emit desired light with minimum color  
shift and minimum deterioration in light emission efficiency,  
20 even when used over an extended period of time.

[0072]

By making the light emitting device in the  
construction as described in claim 6 of the present invention,  
it is made possible to emit light more efficiently with minimum  
25 color shift and minimum deterioration in light emission

efficiency, even when used over an extended period of time.

[0073]

By making the light emitting device in the construction as described in claim 7 of the present invention, it is made possible to emit white light more uniformly in a planar construction with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time.

[0074]

By making the light emitting diode in the construction as described in claim 8 of the present invention, it is made possible to emit white light containing RGB components with high luminance, with minimum color shift and minimum deterioration in light emission efficiency, even when used over an extended period of time under outdoor environment.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a schematic sectional view of the light emitting device of the present invention.

[Fig. 2] Fig. 2 is a schematic sectional view of the planar light source which is another light emitting device of the present invention, while (A) showing the planar light source having the phosphor between the optical guide plate and the light emitting diode, and (B) showing the planar light source having the phosphor on the principal plane of the optical guide plate.

[Fig. 3] Fig. 3 is a schematic sectional view of the light emitting diode which is another light emitting device of the present invention.

[Fig. 4] Fig. 4(A) shows an example of absorption spectrum of the first and the second phosphors used in the present invention, and Fig. 4(B) shows an example of emission spectrum of the first and the second phosphors used in the present invention.

[Fig. 5] Fig. 5 shows an example of emission spectrum of the light emitting component used in the present invention.

[Fig. 6] Fig. 6 shows the results of weatherability test for the comparison of the present invention with the reference light emitting device, while (A) shows a relation between the luminance retaining ratio and the time, and (B) is a graph showing a relation between the color tone and the time.

[Fig. 7] Fig. 7 shows the results of reliability test for the comparison of the present invention with the reference light emitting device, while (A) shows a relation between the luminance retaining ratio and the time, and (B) is a graph showing a relation between the color tone and the time.

[Fig. 8] Fig. 8 shows the chromaticity diagram of light which the light emitting device of the present invention can emit. Points A and B indicate the colors of light emitted by the light emitting device and points C and D indicate the colors of light emitted by two kinds of phosphors.



## [Description of the Reference Numerals]

- 101, 210: Molding material wherein phosphor is contained
- 102, 202, 302: Light emitting component
- 103, 303: Conductive wire
- 5      104: Casing
- 105: External electrode
- 201: Color conversion material
- 203: Support
- 204: Optical guide plate
- 10      205, 207: Reflective material
- 206: Diffusion sheet
- 301: Coating material wherein phosphor is contained
- 304: Molding material
- 305: Mount lead
- 15      306: Inner lead

Fig. 1

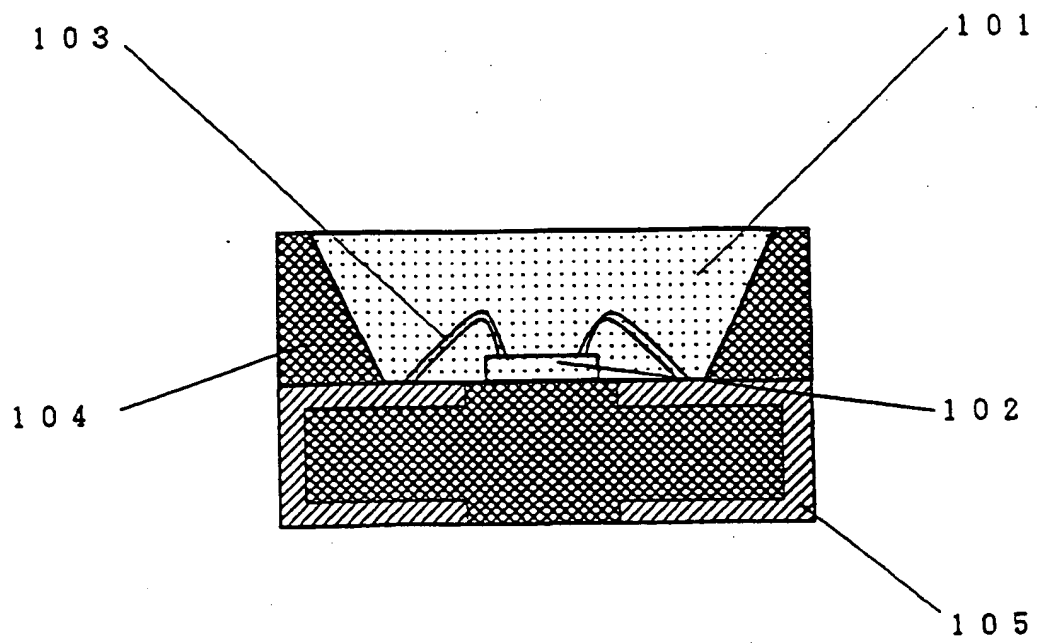


Fig. 2

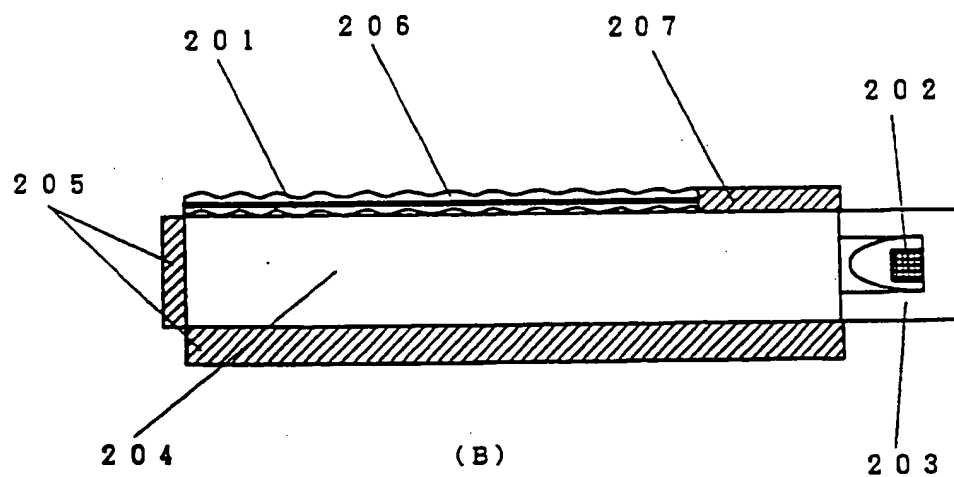
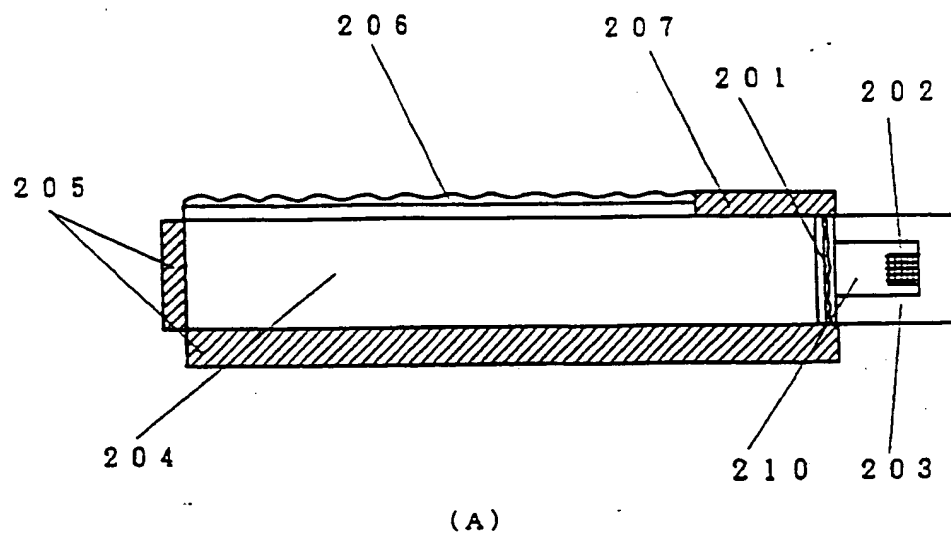


Fig. 3

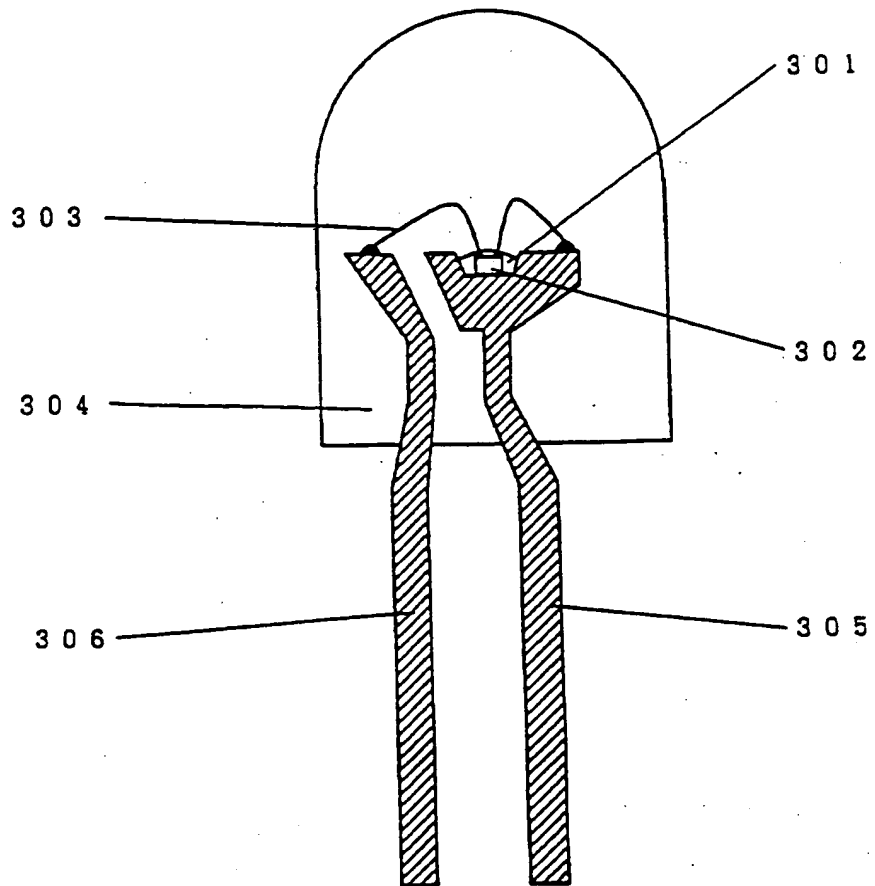


Fig. 4

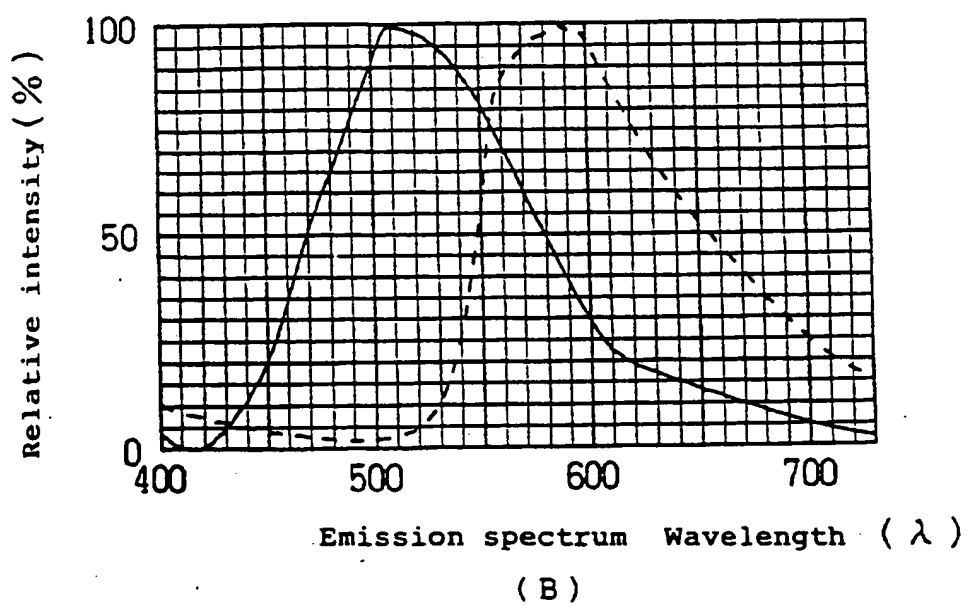
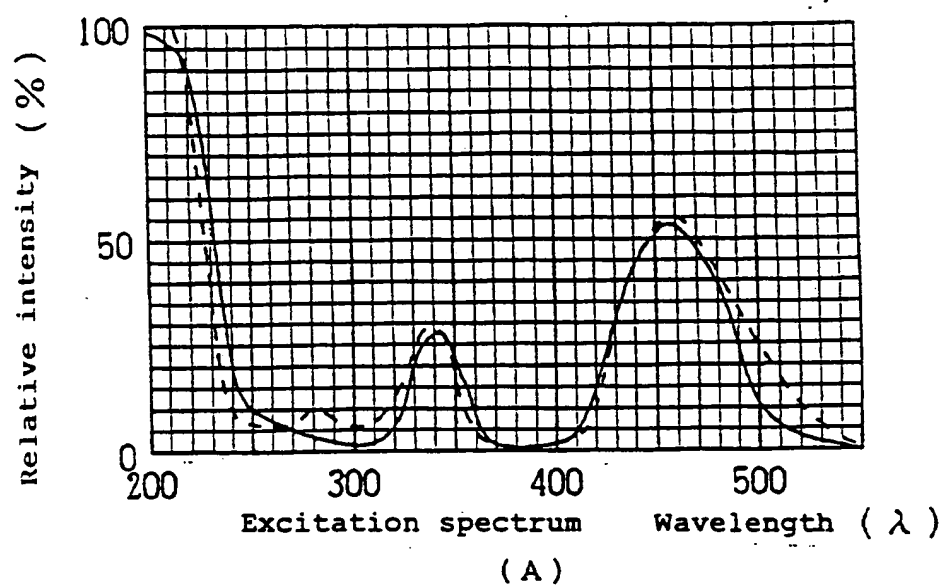


Fig. 5

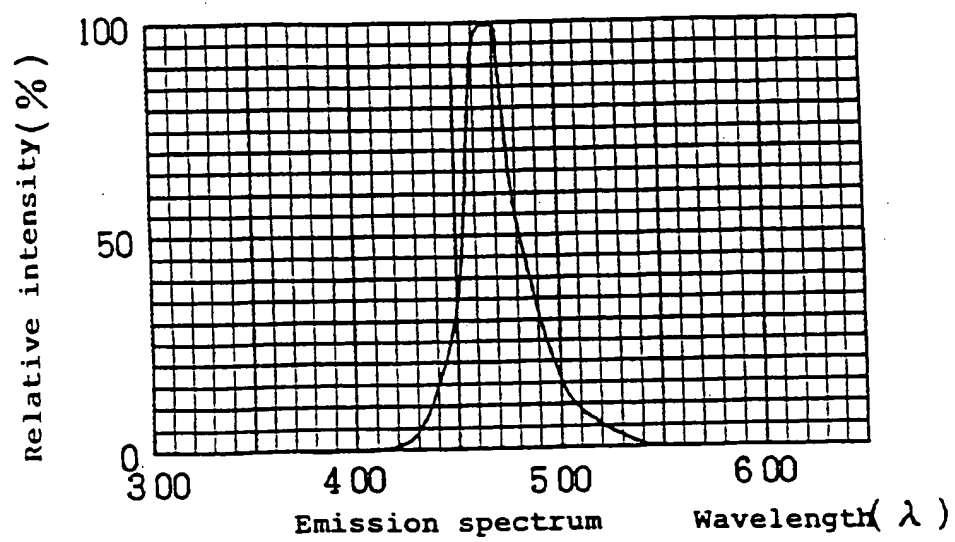


Fig. 6

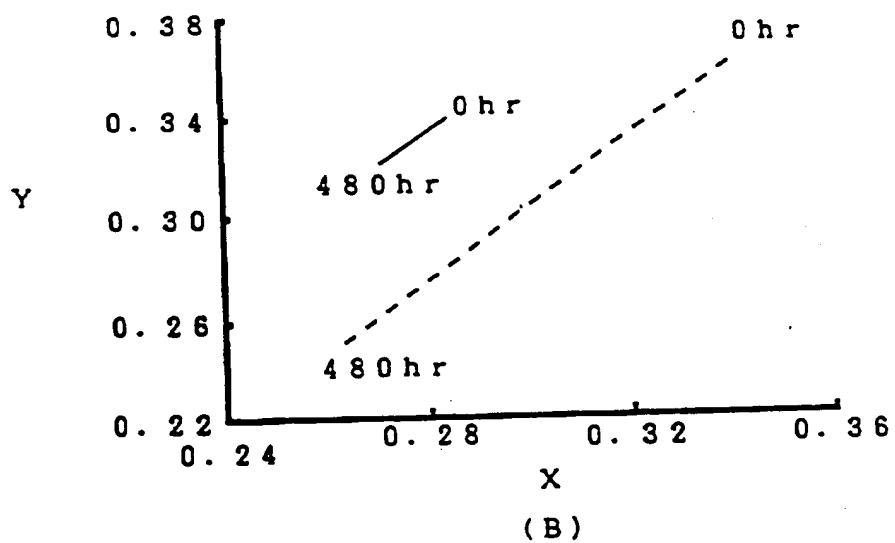
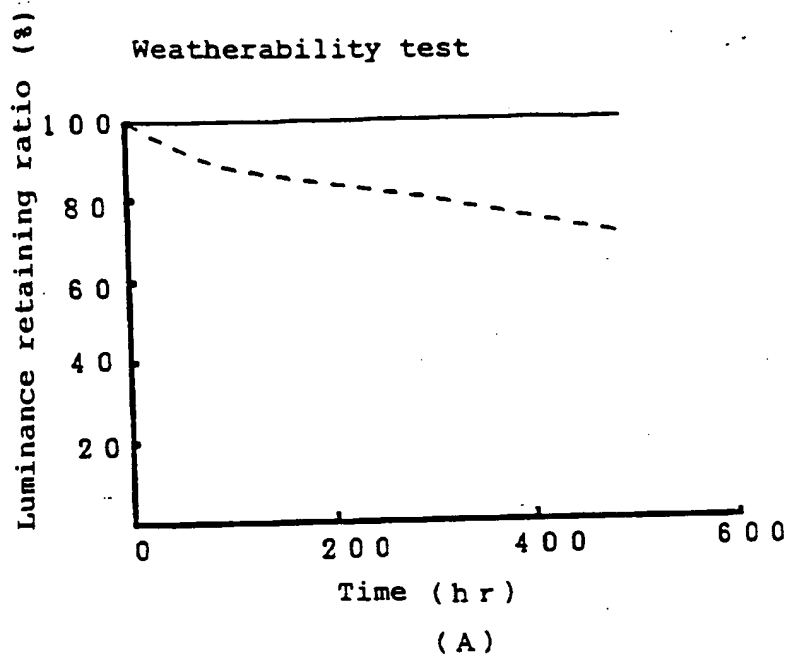


Fig. 7

Reliability test

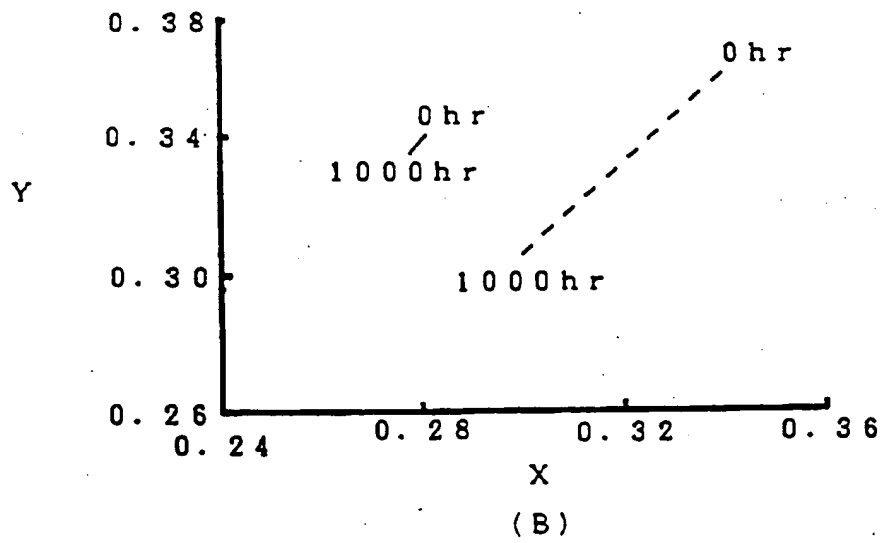
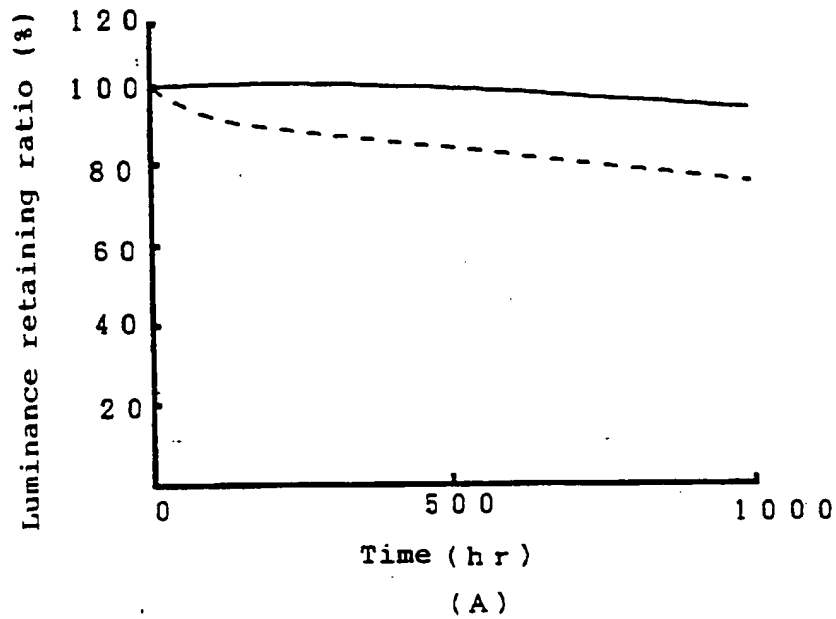
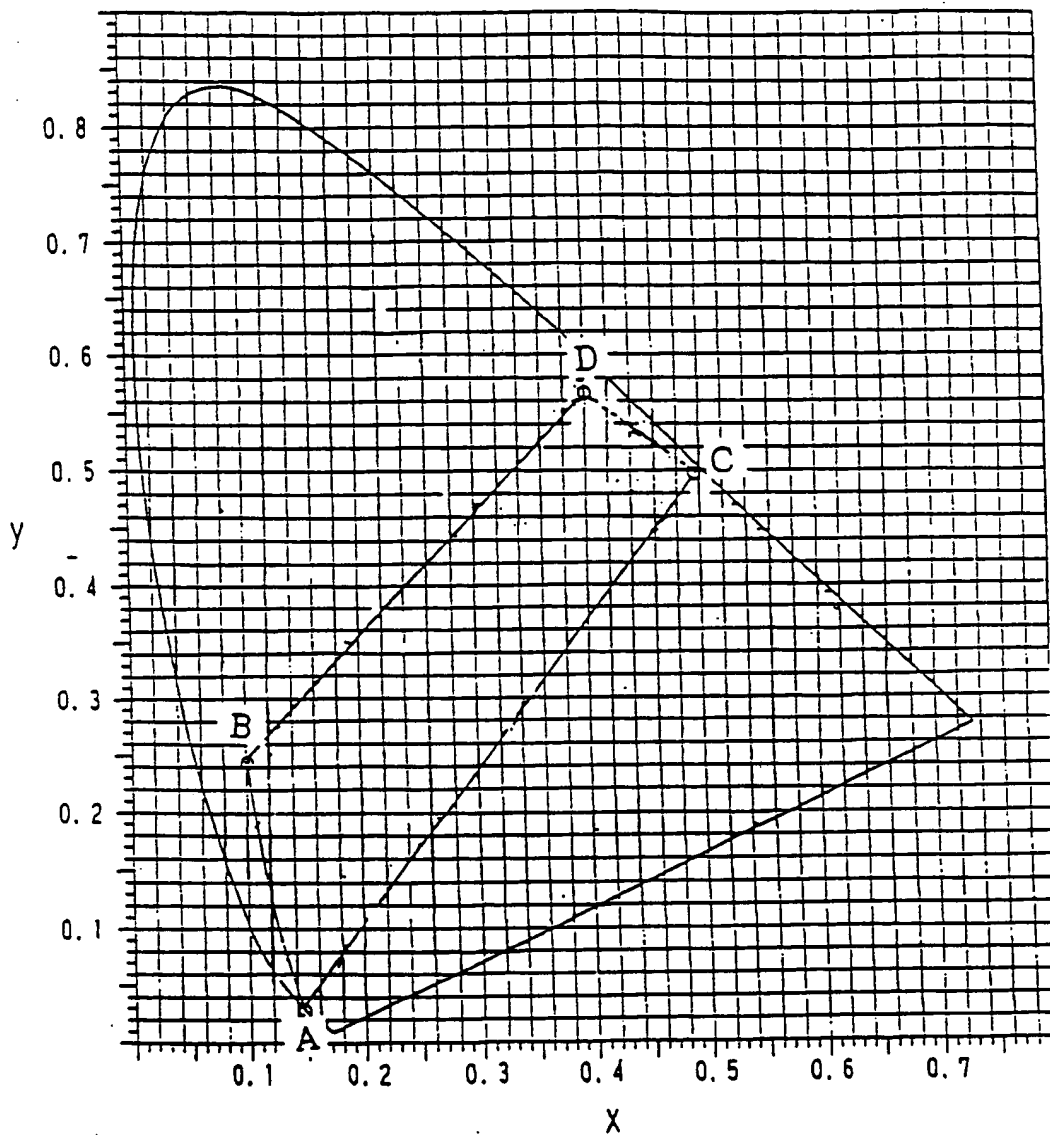




Fig. 8

Fig. 8



[Document Name]      Abstract

[Abstract]

[Object] It is to provide a light emitting device used in back light source, illuminating switch, signal, display, LED  
5 display, indicator, etc and particularly to provide a light emitting device which emits light of desirable color with high luminance and high efficiency regardless of the operating environment.

[Means for solving] The light emitting device has a light  
10 emitting component using a gallium nitride semiconductor as a light emitting layer and a phosphor which absorbs at least a part of light emitted by the light emitting component to emit light of a wavelength longer than that of the light emitted by the light emitting component. The phosphor is composed of two  
15 or more kinds of yttrium-aluminum oxide fluorescent materials activated with cerium having different compositions.

Document Name: Official Correction Data

Corrected Document: Petition for Patent

Approved or Supplemented Data:

Applicant:

Identification No.: 000226057

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Name: Nichia Chemical Industries, Ltd.

## Applicant Record

Identification No.: [000226057]

1. Date of Registration: August 18, 1990 (newly recorded)

Address: 491-100, Oka, Kaminakacho, Anan-shi, Tokushima, Japan  
Name: Nichia Chemical Industries, Ltd.

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